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THE EGRET DATA PRODUCTS

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ABSTRACT

We describe the EGRET data products which we anticipate will suffice for virtually all guest and archival investigations. The production process, content, availability, format, and the associated software of each product is described. This paper also supplies sufficient detail for the archival researcher to do analysis which is not supported by extant software. Where published references don't exist, the EGRET team documentation is cited.

1. INTRODUCTION

The highest energy instrument aboard the Compton Observatory (formerly named GRO) is EGRET (Energetic Gamma Ray Experiment Telescope). The EGRET instrument is described by Kanbach *et al.* (1988, 1989) and Hartman *et al.* (1992). The scientific objectives of the EGRET mission are described by Kanbach *et al.* (1988) and Fichtel *et al.* (1989). On-orbit operation and initial EGRET scientific results are presented by Hartman *et al.* (1992) and Nolan *et al.* (1992).

The EGRET spark-chamber data should be useful for a wide variety of astrophysical investigations because of the high energy range (20 MeV $< E <$ 30 GeV), directional resolution ($\approx 1°$ for individual gamma rays), large sensitive area ($\approx 10^3$ cm^2), good energy resolution ($\approx$20% $\Delta E/E$, for $E >$ 100 MeV where the TASC, Total Absorption Shower Counter is effective), and low background ($<$ 0.1 of the expected diffuse extragalactic gamma ray background).

The EGRET data analysis system has been previously described by Bertsch *et al.* (1989). Their description of the EGRET telemetry and low level data processing will not be repeated. This paper focuses on the current state of the EGRET data products, and expectations for the EGRET data products and associated software which are to be made available through the SSC (Arthur Holley Compton Gamma Ray Observatory Science Support Center; Chipman 1992) as specified by the GRO Project Data Management Plan (July 1990). Because of the intensive analysis and development in progress by the EGRET team and the SSC, it is expected that some of the details given here will soon be obsolete. Current information may be obtained by contacting the SSC or an EGRET team member.

These data products are shown in Table 1. The suffixes (for file types for which more than one file is anticipated) will correspond to entries in an on-line catalog to be maintained by the SSC. It is anticipated that virtually all scientific analyses may be performed using these products (including products specially prepared upon request in these formats by the SSC or the EGRET team). However, excerpts from the PDB (primary data base, Bertsch *et al.* 1989) will be made available if there are exceptions. The EGRET observations which have been completed are shown in Table 2. We intend to make the summary files, exposure history files, and the binned maps for each exposure public domain within 15 months of the end of the corresponding observation. However, if data product preparation for the EGRET team use requires more than 3 months (this appears unlikely at this time), the data products would be made available 12 months after they were prepared for the EGRET team use. GIs (Guest Investigators) who are awarded observation time will be furnished data products following preparation ($\approx$3 months).

The EGRET team will produce binary files which will be converted to FITS with SSC software. The GI (Guest Investigator) could be supplied with these binary files. However, FITS format is recommended since it provides portability and also is well documented via the ASCII header. The SSC will have subroutines available to read these data products using the FITSIO system of Fortran subroutines (Pence, 1991)[1]. FITSIO provides low-level routines for use with Unix, VMS, IBM main frame, or MSDOS operating systems.

Documentation of the techniques and algorithms used by the EGRET software exists in EGRET team documentation (normally the program's specification, program documentation, and user's guide). The EGRET PDB is currently maintained on an IBM MVS system at GSFC, and some of the EGRET team analysis is done on this IBM. The EXPHISTfiles are currently produced only on the IBM. However, all of the other data products are produced and used on a cluster of Sun workstations at GSFC. The Max Planck EGRET group produces and uses EGRET data products on an IBM CMS system (although they recently have acquired a Sun workstation). The Stanford EGRET group produces and uses EGRET data products on a cluster of Sun workstations. The EGRET software currently uses the TEMPLATE graphics system, but IDL is being used to an increasing extent.

Many of the EGRET team analysis capabilities will be ported to the SSC for use by GIs, and to some extent, for remote usage by the larger astrophysical community. The SSC bulletin board should be consulted for current status[2].

2. SUMMARY & SELECT GAMMA RAY DATA BASE

As described by Bertsch *et al.* (1989), the EGRET telemetry is processed by the program PDBGEN to produce the PDB, which contains $\approx$600 bytes per spark-chamber event. PDBGEN includes the SAGE (Search and Analysis of Gamma Ray Events) subroutine which structures the spark-chamber tracks before the gamma-ray directions and energies are ascertained. The information relevant to gamma-ray astronomy is extracted for the summary and select files. Also, the summary and select files contain only events which are judged (either automatically by SAGE or by human review (Nolan *et al.*, 1992; Bertsch *et al.* 1989) to be due to celestial[3] gamma rays. The format of the summary data base is shown in Table 3. Many of the details in the PDB are not included[4] in the summary database.

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[1] Email: pence@tetra.gsfc.nasa.gov or LHEAVX::PENCE

[2] Telnet to grossc.gsfc.nasa.gov (or set host to GROSSC), and login as gronews. The same information may be obtained by calling the SSC (301)286-6257.

[3] Events within an energy dependent angle of the earth horizon (and thus probably due to cosmic ray induced atmospheric albedo gamma rays) will not be included in the summary and select files. The energy dependent angle is currently TBD (to be determined).

[4] The following are in the PDB, but not in the summary files or EXPHISTfiles: spark chamber data, trigger-telecope time of flight, TASC PHA timing measurements, various count rates, analysis program version numbers, editor identification, structuring summary parameters, scattering energy estimate and uncertainty, TASC PHA energy, and housekeeping data. Complete content and format details are available in EGRET team documentation (EGRET/GSFC/DLB/NAL/FORMATS).

Table 1. The EGRET Data Products

Name	Description	Format	Size	Numeration
Low level	processed products			
SUMMARYpppp	Summary of events	binary table FITS	≈10 Mbytes/2 weeks[1]	by Obs.
SELECTFxxxx	Subset of SUMMARY files	binary table FITS	≈100 Kbytes[1]	SSC catalog
TIMELINfile	EGRET Timeline	ASCII table FITS	≈10 Kbytes	1 expected
EXPHISTpppp	Exposure history	ASCII table FITS	≈350 Kbytes/2 weeks	by Obs.
SENHISTxxxx	Sensitivity history	ASCII table FITS	≈50 Kbytes/2 weeks	SSC catalog
BURSTCSxxxx	Burst mode counts spectra	binary table FITS	≈100 Kbytes[2]	SSC catalog
SOLARCSxxxx	Solar mode counts spectra	binary table FITS	≈100 Kbytes[2]	SSC catalog
BKGNDCSxxxx	Background counts spectra	binary table FITS	≈100 Kbytes[2]	SSC catalog
High level	processed products			
PSFFILExxxx	Point spread function tables	binary table FITS	16.3 Mbyte	SSC catalog
EDPFILExxxx	Energy dispersion tables	binary table FITS	16.3 Mbyte	SSC catalog
SARFILExxxx	Sensitive area tables	binary table FITS	160 Kbyte	SSC catalog
SARVARYfile	Sensitivity time dependence	ASCII table FITS	≈10 Kbyte	1 expected
BURSTRMxxxx	Burst Response matrices	binary table FITS	≈40 Kbytes/matrix	SSC catalog
CNTSMAPnnnn	Binned event counts maps	FITS format	≈400 Kbytes/Obs.[3]	by Obs.[4]
EXPOMAPnnnn	Binned exposure maps	FITS format	≈400 Kbytes/Obs.[3]	by Obs.[4]
INTSMAPnnnn	Binned intensity maps	FITS format	≈400 Kbytes/Obs.[3]	by Obs.[4]
DIFFMAPnnnn	Diffuse prediction maps	FITS format	≈400 Kbytes	SSC catalog
SRCECATfile	Source catalog	FITS format	≈10 Kbyte	1 expected
HESPECTxxxx	High energy spectra	FITS format	≈10 Kbyte	SSC catalog
HELTCRVxxxx	High energy light curves	FITS format	≈10 Kbyte	SSC catalog
BURSCATfile	Burst catalog	FITS format	≈10 Kbyte	1 expected
BURSTPSxxxx	Burst photon spectra	FITS format	≈10 Kbyte	SSC catalog
BULTCRVxxxx	Burst light curves	FITS format	≈10 Kbyte	SSC catalog
SOLRCATfile	Solar flare catalog	FITS format	≈10 Kbyte	SSC catalog
SOLARPSxxxx	Solar flare photon spectra	FITS format	≈10 Kbyte	1 expected
SOLTCRVxxxx	Solar flare light curves	FITS format	≈10 Kbyte	SSC catalog
EGRETPBfile	EGRET publication catalog	ASCII table FITS	≈10 Kbyte	1 expected

[1]Header plus 130 bytes/event, see table 3 for format; also called time-ordered gamma-ray event lists.

[2]Header plus 1230 bytes/spectrum

[3]For fourteen images each $60° \times 60°$maps with $1/2°$ binning; one map for each of the following tentative energy selections; first ten narrow bands (which will be appropriate for spectroscopy): $30 < E < 50$ MeV, $50 < E < 70$ MeV, $70 < E < 100$ MeV, $100 < E < 150$ MeV, $150 < E < 300$ MeV, $300 < E < 500$ MeV, $500 < E < 1000$ MeV, $1000 < E < 2000$ MeV, $2000 < E < 5000$ MeV, $5000 < E < 30000$ MeV; and then four integral bands (which will be appropriate for source detection and position determination, and extended emission distribution studies): $E > 30$ MeV, $E > 100$ MeV, $E > 300$ MeV, $E > 1000$ MeV.

[4]Normally nnnn will be the Observation period number $\times 10$. However multi-pointing maps (with number suffix _xxx) will be available and will be cataloged on line by the SSC.

Table 2. Completed Phase I EGRET Observations

Obs. period	Target name	Begin	End
0.2	CRAB 3° (L=186, B= −3)	22 APR 1991	28 APR 1991
0.3	CRAB 9° (L=193, B= −4)	28 APR 1991	1 MAY 1991
0.4	CRAB 9° (L=193, B= −4)	1 MAY 1991	4 MAY 1991
0.5	CRAB 0° (L=184, B= −6)	4 MAY 1991	7 MAY 1991
0.6	GALACTIC HOLE (L=150, B=53)	7 MAY 1991	10 MAY 1991
0.7	VELA (L=266, B=1)	10 MAY 1991	16 MAY 199
1.0	CRAB[a]	16 MAY 1991	30 MAY 1991
2.0	CYGNUS	30 MAY 1991	8 JUN 1991
2.1	SUN	8 JUN 1991	15 JUN 1991
3.0	SN 1991T	15 JUN 1991	28 JUN 1991
4.0	NGC 4151	28 JUN 1991	12 JUL 1991
5.0	GAL CENTER	12 JUL 1991	26 JUL 1991
6.0	SN 1987A	26 JUL 1991	8 AUG 1991
7.1	CYGNUS	8 AUG 1991	15 AUG 1991
7.2	GAL PLANE 25	15 AUG 1991	22 AUG 1991
8.0	VELA	22 AUG 1991	5 SEP 1991
9.1	GAL SOUTH POLE	5 SEP 1991	12 SEP 1991
9.2	HERCULES	12 SEP 1991	19 SEP 1991
10.0	FAIRALL 9	19 SEP 1991	3 OCT 1991
11.0	3C 273	3 OCT 1991	17 OCT 1991
12.0	CEN A	17 OCT 1991	31 OCT 1991
13.1	GAL PLANE 25	31 OCT 1991	7 NOV 1991
13.2 — 33.0	SUBSEQUENT OBS.[b]	7 NOV 1991	20 AUG 1992

[a] More details about these observations are given by Chipman (1992).
[b] A tentative schedule for the subsequent observations is given by Chipman (1992).

For investigators using SSC or EGRET team software, the detail given in Tables 3 & 4 will not be required. The software will be designed to operate correctly without user involvement in the details of the data products. The details are included in anticipation of the eventual creation of new software for archival analysis of summary data. The details given in Table 3 & 4 should suffice for this. The parameters documented only in EGRET team software are not anticipated to be useful.

The investigation of a specific source uses gamma rays from a radius corresponding to the extent of the PSF (point spread function), typically $\approx 5°$. Since EGRET simultaneously observes a cone of radius $\approx 30°$, only a small fraction of the events in a SUMMARYfile will be useful for an investigation of a specific source. The SELECTFiles will contain subsets of the SUMMARYfiles for the purposes of specific source investigations.

SELECTFiles will be produced at the SSC or by the EGRET team using the SELECT program. Events are chosen which meet user specified criteria[5]. The events which meet the criteria are written

[5] Direction within a specified region (either inside or outside of a circle, or a square; in either galactic or celestial coordinates); gamma-ray direction less than a specified maximum from the detector axis; gamma-ray earth zenith angle less than a specified maximum; gamma-ray energy between specified minimum and maximum; energy class: either A, A+B+C, A+C, B, or C (see Table 3, footnote 12); energy deposition in TASC above 6.5 MeV; specific Compton Observatory position (by earth latitude and longitude, or by rigidity); specific packet error flag conditions; specific analysis return code conditions.

to the SELECTFile in the same format as the SUMMARYfile.

The SSC or the EGRET team will provide the GI with the use of the following software which will analyze SELECTFiles: the PULSAR program constructs a binned light curve from the events in the SELECTFile for a specific pulsar ephemeris (correction may also be done for a binary orbit); the SEARCH program performs an epoch folding search in period for significant periodicity; the MAPGEN program constructs a binned counts map (also may use a SUMMARYfile); the QIKLOOK program allows for examination of individual records, and also allows easy installation of code for specific analyses. The SSC will make available the Fortran code for the QIKLOOK program.

An example of a special SELECTFile to be made available by the SSC is that containing the gamma-ray spark-chamber events associated with the May 3 gamma-ray burst (Schneid *et al.* 1991).

3. EGRET EXPOSURE

The calculation of the EGRET exposure is complicated because of measures taken to limit the rate of events due to cosmic-ray induced atmospheric-albedo gamma rays. The 32 scintillator tiles of the time-of-flight spark-chamber-trigger system form 96 recognized pairs which are grouped into 9 sub-telescope directions (Bertsch *et al.* 1989, fig. 4): vertical, and the 8 cardinal directions (for convenience designated E, NE, N, NW, W, SW, S, SE; see Table 3, footnote 3). These sub-telescope directions are individually commanded off by the Compton Observatory computer when their center is within 22° of the earth's atmosphere. The 9 sub-telescope directions can combine to form 74 possible combinations or sub-telescope modes. The EGRET sensitive area is different for each of these modes. However, some albedo gamma-ray events still cause events despite this measure. Therefore, the event by event earth zenith selection offered by the SELECT program is normally required, and must be accounted for when calculating exposure.

The TIMELINfile is a short file describing the beginning and ending time, and times for which data is to be excluded for various reasons from analysis. The first step in determining the EGRET exposure is the construction of the EXPHISTfile (exposure history) for each observation period from the TIMELINfile and the PDB with the EXPHST program (currently running only at GSFC on the IBM MVS system). The format of the EXPHISTfile is shown in Table 4. A new record is written to the file each time the EGRET operation mode changes, along with the integral of the live-time (dead time is created by event readout, and anticoincidence-dome interactions) for that time period.

The EXPHISTfile and the instrument response tables (section 5) are used by the INTMAP program to produce a binned map of exposure (EXPOMAPfiles). A CNTSMAPfile is used as a template for the binning and energy range selection. Thus the INTMAP program creates an EXPOMAPfile which corresponds exactly to a specific CNTSMAPfile. The INTMAP program simultaneously produces an intensity or flux map (INTSMAPfile) by dividing the CNTSMAP by the EXPOMAP.

The PNTEXPOS program (tentative name) uses the EXPHISTfile and the instrument response files to produce a table of instrument sensitive areas as a function of time for a specific direction and energy range (tentative data product name, SENHISTxxxx) which may subsequently be used to analyze source variability.

4. BINNED MAPS

The binned counts maps (CNTSMAPfiles) are produced from SELECTFiles or SUMMARYfiles with the MAPGEN program either in celestial or galactic coordinates. The exposure map (EXPOMAPfile) and intensity map (INTSMAPfile) are produced by the INTMAP program.

Table 3. EGRET Summary & Select Data Base Content

Content of each 130 byte record	Type	Start byte
Time in milliseconds of day[1]	I*4	1
Additional microseconds	I*2	5
Integer value of Modified Julian Date, (JD - 2440000.5)	I*2	7
Compton Observatory X position (J2000 earth centered inertial coordinate in km)	R*4	9
Compton Observatory Y position (J2000 earth centered inertial coordinate in km)	R*4	13
Compton Observatory Z position (J2000 earth centered inertial coordinate in km)	R*4	17
Trigger-telescope hits[2]	I*4	21
Trigger-telescope directions and types enabled[3]	I*2	25
Packet error flags[4]	I*2	27
TASC pulse height analyzer #1 flags[5]	Byte	29
TASC pulse height analyzer #2 flags[5]	Byte	30
Spare	I*2	31
Gamma-ray projected direction X-Z (radians)	R*4	33
Gamma-ray projected direction Y-Z (radians)	R*4	37
Gamma-ray Earth Zenith (radians)	R*4	41
Gamma-ray Earth Azimuth (radians from North toward East)	R*4	45
continued on the next page		

[1]This is the time from the beginning of the Modified Julian Day to the event in milliseconds. Thus the time of the event may be obtained from the first three integers in the record. The absolute timing accuracy is ≈50 microseconds. The relative accuracy is 8 microseconds.

[2]The 32 bits in this integer indicate (1 means a hit) the state of each scintillator tile in the upper (B) plane, and lower (C) plane of the time-of-flight spark-chamber-trigger hodoscope (Hunter 1991; Bertsch *et al.* 1989, fig. 4). The tile order is (from low to high bit): C11, C12, C13, C14, C21, C22, C23, C24, C31, C32, C33, C34, C41, C42, C43, C44, B11, B12, B13, B14, B21, B22, B23, B24, B31, B32, B33, B34, B41, B42, B43, B44. The first index increases with increasing X. The second index increases with increasing Y.

[3]The first 15 bits in this integer indicate which trigger telescope directions and tile combination types (Bertsch *et al.* 1989) were enabled at the time of the event. The order is (from low to high bit; 1 means enabled): T1 (vertical central), T2 (vertical edge), T3 , T4, T5, T6, T7, D1=E, D2=NE, D3=N, D4=NW, D5=W, D6=SW, D7=S, D8=SE, unused. North is in the direction of the EGRET positive Y axis, and East is the direction of the EGRET positive X axis. The EGRET axes are aligned with the Compton Obervatory axes. The types are the combinations of tiles with similar expected background. The definitions may be found in EGRET team documentation (EGRET/GSFC/DLB/85/AUG/15). Types T1 and T2 are also the on-axis direction. All EGRET observations to date (except for several hours during instrument activation) have been made with all types enabled. However T1 and T2 are turned off if the earth limb is within 22° of the center of their direction (just as directions D1-D8).

[4]These flags indicate problems with the integrity of the telemetry. They are explained in EGRET team documentation (EGRET/GSFC/DLB/NAL/FORMATS). Generally, significant periods of problematic telemetry are removed by exclusion entries in the TIMELINfile.

[5]The 8 bits in this byte contain the TASC PHA (pulse height analyzer) flags. The order is (from low to high, 1 means yes): unused, ADC Busy At MET (master event trigger), timer OK at MET (TMOK), energy underflow (RNDN-C), energy overflow, zero cross overflow, rundown time overflow (PHA delay overflow), and zero cross hazard. The meanings of these flags are described in EGRET team documentation (EGRET/SU/PLN/87/OCT/9). The zero cross overflow bit will be 1 if less than 6.5 MeV was deposited in the TASC. This is important since the normal "TASC in coincidence" calibration files (section 5) pertain to a selection of events with at least 6.5 MeV energy deposition in the TASC. There is one byte for each TASC PHA.

Table 3. continued

Content	Type	Start byte
Gamma-ray Right Ascension (radians, J2000)	R*4	49
Gamma-ray Declination (radians, J2000)	R*4	53
Gamma-ray Galactic Latitude (radians, BII)	R*4	57
Gamma-ray Galactic Longitude (radians, LII)	R*4	61
Gamma-ray energy (MeV)	R*4	65
Gamma-ray energy uncertainty (MeV)	R*4	69
Spares	2I*4	73
Time correction to Barycenter[6]	R*8	81
Binary orbit phase at the time of the event (values 0 to 1)	R*4	89
Pulsar phase at the time of the event (values 0 to 1)	R*4	93
Pulsar Right Ascension (J2000, radians)	R*4	97
Pulsar Declination (J2000, radians)	R*4	101
Barycenter position X (J2000 earth centered inertial coord. in light microseconds)	I*4	105
Barycenter position Y (J2000 earth centered inertial coord. in light microseconds)	I*4	109
Barycenter position Z (J2000 earth centered inertial coord. in light microseconds)	I*4	113
Structure Analysis processing return code[7]	Byte	117
SINGLE subroutine return code[8]	Byte	118
SAGE subroutine return code[9]	Byte	119
Structure Flags[10]	2 Bytes	120
SCATTERING subroutine return code[11]	Byte	122
ENERGY subroutine return code[12]	Byte	123
DIRECTION subroutine return code[13]	Byte	124
Spares	3I*2	125

[6]The time correction to the solar system barycenter, T_C, can be used to calculate the arrival time at the barycenter for the pulsar direction specified in bytes 97–104. The barycentric arrival time is: Modified Julian Date $= IMJD + T_C + 0.5$; or full Julian Date $= IMJD + T_C + 2440001.$, where $IMJD$ is the integer value at byte 7. This and the next seven numbers are written to SELECTFiles by the PULSAR program. SUMMARYfiles will also contain the Barycenter vector for the time of each event.

[7]The Structure Analysis bit meanings are: bit 0, event disposition (1=Editor Last Set Disposition); bit 1, Two Tracks In X-View (1=yes); bit 2, Two Tracks In Y-View (1=yes); bits 3-4, Track Correlation Method (0 = Spark Density/Track Length, 1 = Gap Method, 2 = 45 Degree Grid Method); 5-7, Unused.

[8]The SINGLE return code also characterizes the presence of single or multiple tracks in the XZ and YZ projections. A detailed description is in the header of the SINGLE subroutine Fortran code.

[9]The SAGE return code characterizes the overall SAGE event structuring. A detailed description is in EGRET team documentation (The SAGE Document, chapter V).

[10]The 16 structure flags further characterize the SAGE structuring of the spark chamber events. The meanings of these flags are described in EGRET team documentation (The SAGE Document, chapter IX).

[11]The SCATTERING return code characterizes the determination of the energy of the lepton for each track from the extent of Coulomb scattering. A detailed description is in the header of the SCATTERING subroutine Fortran code.

[12]The ENERGY return code characterizes the assessment of the gamma-ray energy. Bits 0&1 describe the event class: 0, Class A – Best events for spectroscopy (all tracks hit TASC and both TASC PHAs are above threshold); 1, Class B – Lesser quality events because tracks show that much of the energy is not measured by TASC; 2, Class C – Like class A, but below PHA threshold. Energy is low, but estimate very uncertain; 3, No energy assigned – bits 3-7 give reason(s) for not assigning an energy. See the header of the ENERGY subroutine Fortran code for details.

[13]The DIRECTION return code characterizes the gamma-ray direction determination from an energy weighted average of the track directions. A detailed description is in the header of the DIRECTION subroutine Fortran code.

The exposure maps have units of cm^2 second steradian, where the solid angle is that of the specific bin. Thus, the intensity maps have units of cm^{-2} $second^{-1}$ $steradian^{-1}$. A point source flux (units, cm^{-2} $second^{-1}$) is the integral of the intensity over the solid angle into which it is dispersed by the EGRET PSF. However, because of diffuse gamma-ray emission, a simple integral is not appropriate.

The SSC or the EGRET team sites will provide the GI with the use of the following software which will analyze binned maps: the SKYMAP program produces a color display of a binned map (using X11 interactive graphics on a workstation) which may also be printed; the SHOW program provides for map evaluation. The following functions are available: display pixel values for specified coordinates; display in order of decreasing value for a region; make a one dimensional profile of a region of the map by integrating over the other dimension; integrate pixel values for a rectangular or circular region. The SOURCE program evaluates the likelihood of the existence of a source at a specific point. For a significant indication of a source, it provides an estimate of the number of source counts and the uncertainty of that estimate. The exposure from the appropriate EXPOMAPfile is then used to obtain the point-source flux. The SPECTRAL program tentatively uses SOURCE to obtain an estimate of the number of source counts in each of many energy selection bands (e.g. the 10 bands of footnote 3 of Table 1), and then uses the EXPHISTfile, and the instrument response files for a forward-folding chi-squared-minimization estimate of the source photon spectrum.

Binned maps of counts, exposure, and intensity will be available 15 months after data are acquired for a 60° by 60° square region centered on the Z axis for each observation with a separate image for each of the 14 gamma-ray energy selections given in footnote 3 of Table 1. Special maps will eventually be available of all extant data in specific directions of interest. For example, maps will be made available (≈9/92) of the ≈5 weeks of exposure obtained between April and June of the Crab/Geminga region. Also, binned maps will eventually be available (≈11/93) for the entire galactic plane (tentatively $|b| < 20°$), and the full sky (probably as a binned Aitoff projection). Also binned maps of the EGRET team estimate of galactic and extragalactic diffuse gamma-ray emission (DIFFMAPfiles) will eventually be available (see section 7).

5. CALIBRATION RESULTS

The SLAC (Stanford Linear Accelerator Center) calibration data have been analyzed at GSFC with software equivalent to that used to analyze flight data. The resulting gamma-ray energies and directions have been analyzed by the Max Planck EGRET group with program CALAN to obtain the response tables. A description of these results is in preparation (Thompson *et al.* 1992). The SLAC data have been analyzed to determine the EGRET response for each of the 74 sub-telescope modes (discussed in section 3). The response tables are SARFILEfiles (Sensitive area), PSFFILEfiles (Point spread function), and EDPFILEfiles (Energy dispersion). The suffix of these files correspond to EGRET operation conditions[6].

The sensitive area tables consist of a four byte floating number for twenty different true gamma ray energies[7] in each record. There are 1998 records: 74 sub-telescope modes × 3 azimuths (0°, 22.5°, 45°, with respect to the X axis) × 9 inclinations (0°,5°,10°,15°,20°,25°,30°,35°, 40°, with respect to the Z axis).

[6] The currently assigned suffixes are: suffix 01, event classes (A+B+C) & TASC not in coincidence; suffix 02, event classes (C) & TASC not in coincidence; suffix 03, event classes (A+C) & TASC not in coincidence; suffix 04, event classes (A) & TASC not in coincidence; suffix 05, event classes (B) & TASC not in coincidence; suffix 06, event classes (A+B+C) & TASC in coincidence at 6.5 MeV; suffix 07, event classes (A) & TASC in coincidence at 6.5 MeV; suffix 08, event classes (B) & TASC in coincidence at 6.5 MeV; suffix 09, event classes (C) & TASC in coincidence at 6.5 MeV; suffix 10, event classes (A+C) & TASC in coincidence at 6.5 MeV.

[7] True energies (in MeV): 15, 20, 30, 35, 50, 60, 70, 100, 150, 200, 300, 500, 700, 1000, 2000, 3000, 4000, 6000, 7000, 10000.

Table 4. EGRET Exposure History File Content

Content	format	Column
Comment indicator ('*' means entire record is a comment)	A1	1
Integer value of Modified Julian Date, (JD - 2440000.5)	I6	2
Time in milliseconds of day[1]	I9	18
Spare	L1	17
SAA Flag, 'T' when the Compton Observatory is in the SAA	L1	18
Pointing deviation flag ('T' if *Compton* pointing deviation $> 0.5°$)	L1	19
Exclusion flag ('T' if interval excluded by TIMELINfile during calibration, etc.)	L1	20
Spare	Z1	21
Hexadecimal value of hodoscope directions and types enabled[2]	Z4	22
Spare	Z1	26
Hexadecimal value of the event coincidence requirement[3]	Z1	27
Spare	Z1	28
Hexadecimal value of the TASC #1 coincidence energy deposition requirement [4]	Z1	29
Spare	Z1	30
Hexadecimal value of the TASC #2 coincidence energy deposition requirement [4]	Z1	31
Compton Observatory Z axis Right Ascension (J2000, radians)	F8.4	32
Compton Observatory Z axis Declination (J2000, radians)	F8.4	40
Compton Observatory X axis Right Ascension (J2000, radians)	F8.4	48
Compton Observatory X axis Declination (J2000, radians)	F8.4	56
Integrated live-time for this exposure record (seconds)	F7.1	64
Elapsed time for this exposure record (seconds)	F10.3	71
Earth center Right Ascension at beginning of record (J2000, radians)	F8.4	81
Earth center Declination at beginning of record (J2000, radians)	F8.4	89
Earth center Right Ascension at end of record (J2000, radians)	F8.4	97
Earth center Declination at end of record (J2000, radians)	F8.4	105

[1]This is the time from the beginning of the Modified Julian Date to the event in milliseconds. Thus the time for the beginning of the exposure record may be obtained from the first two integers in the record.

[2]The bits in this integer indicate (1 means enabled) which trigger hodoscope directions and tile combination types were enabled for the duration of this exposure history record (beginning at the time specified in the first two integers, and ending the Elapsed time later). The order is (from low to high bit): T1 (vertical central), T2 (vertical edge), T3 , T4, T5, T6, T7, D1=E, D2=NE, D3=N, D4=NW, D5=W, D6=SW, D7=S, D8=SE, unused. See table 3, footnote 3 for more information. Two important values are 7FFF for unocculted observation, and 007C for complete occultation.

[3]A bit value of 1 means the subsystem signal is included in the coincidence logic requirement. Bit 0, unused; bit 1, Anti-coincidence dome requirement; bit 2, TASC energy deposition requirement; and bit 3, trigger time-of-flight requirement.

[4] This integer represents the minimum energy deposition required in the specific TASC PHA for a spark-chamber event to occur. The levels corresponding to the hexadecimal values are: 0, 1.0 MeV; 4, 2.6 MeV; 8, 5.7 MeV; C, 13. MeV. Flight operation to date has been with a minimum TASC energy deposition of 2.6 MeV required.

It is observed that the EGRET sensitive area decreases as the spark-chamber gas ages. After the gas replacement (the first of five replacements is planned for December 2, 1991), it is expected that the sensitivity will return to the pre-deployment condition. The result will be a saw-tooth variation of sensitivity with time. This variation will be described by the SARVARYfile. The format is not yet determined.

The point spread function tables consist of a four byte floating number for 100 angles — 0.1°, 0.3°, ...19.9° (the first four bytes of the record is a flag, and the last four indicate the overflow, the point spread probability which extends beyond 19.9°) in each record. More specific documentation may be found in the FITS format header for these files. There are 39960 records: 74 sub-telescope modes × 3 azimuths × 9 inclinations × 20 true gamma ray energies[7].

The energy dispersion tables consist of a four byte floating number for 100 energies — fractions of 0,.02,...1.98 of the true energy (the first four bytes of the record is a flag, and the last four indicate the overflow, the energy dispersion probability which extends beyond 1.98 of the true energy), in each record. There are 39960 records as for the point spread function tables.

The SSC will be able to supply Fortran subroutines to access and interpolate these tables.

6. TASC SOLAR & BURST MODES

In addition to its primary role of providing energy resolution for gamma rays recorded by the spark chamber, the TASC also functions independently as a spectrometer for gamma rays between 1 and 190 MeV. Also, four TASC rates (for energy thresholds 1., 2.5, 7., and 20 MeV) are obtained in 2.048 second intervals; and the anticoincidence-dome rate (energy thresholds $\approx$20 keV) is obtained in 0.256 second intervals. The large mass of NaI(Tl) (400 kg) provides omni-directional sensitivity for high energy gamma rays. However, there is no charged particle veto, and there is considerable mass in front of the crystal in most directions (minimum 0.6 radiation lengths along the instrument axis).

There are two modes of TASC spectroscopy, Solar and Burst (Nolan *et al.*, 1992; Hartman *et al.*, 1992). The Solar spectra are continuously accumulated for intervals of 32.768 seconds. The Burst spectra are obtained over 4 preset intervals following a BATSE trigger. Both spectral modes have a common format. The logarithmic channel compression of the 256 channels is given by Bertsch *et al.*(1989, Table II). However, the energy to channel conversion varies with the TASC PMT gains — which have been drifting during the mission. (This effect is corrected by the ENERGY subroutine of the PDBGEN program for spark-chamber events.) These spectra are extracted from the PDB by the program TBURST. Each spectrum forms a 1230 byte record (see EGRET/GSFC/DLB/NAL/FORMATS for the format). The SSC plans to make some of these spectra available in binary table FITS format.

The BATSE-triggered counts-spectra will form the BURSTCSfiles. These tentatively will be made available for the BATSE bursts which are apparent in TASC, or for specifically requested BATSE bursts. The Solar-mode counts-spectra will form the SOLARCSfiles. These tentatively will be made available for solar flares which are apparent in TASC, or specifically requested intervals. The BKGNDCSfiles will offer a collection of spectra which can be used to estimate the TASC background for an event at a specific Compton Observatory orbital position and orientation. The BURSTRMfiles will contain TASC energy-dispersion matrices obtained for specific directions (in Compton Observatory reference frame) with the Compton Observatory Mass Model (Hartman *et al.*, 1992). These matrices are used to obtain the photon spectra (BURSTPSfiles and SOLARPSfiles).

7. OTHER HIGH LEVEL DATA PRODUCTS

In addition to the calibration results, and the binned maps which have already been discussed, the following EGRET high level data products will tentatively be produced. The exact formats for these products is currently uncertain. ASCII table FITS will be used. This will allow the product to be well documented. The ASCII information will be accessible for perusal via some texteditors (ASCII table FITS files have

2880 byte records). Also, the products may be read with software which is easily created (e.g., the FITSIO system) for high level analysis.

The SRCECATfile will be a catalog of sources detected with the EGRET spark chamber. The information given for each source will tentatively include: position, positional uncertainty, intensity above several different energies, intensity uncertainties, spectral information (either a spectral index, or a spectral parameter — the ratio of flux for different energy selections), the spectral uncertainty, and (possible) identification. The HESPECTfiles will give the spectra for sources detected with the EGRET spark chamber which are sufficiently intense. Spectra of the diffuse gamma-ray radiation by sky region will also be available as HESPECTfiles. The HELTCRVfiles will provide the light curves for sources detected with the EGRET spark chamber which are sufficiently intense. For pulsars or other periodic sources, the data will be epoch folded.

The BURSCATfile will contain a catalog of the BATSE bursts apparent in the TASC Burst mode. The contents are currently uncertain. The BURSTPSfiles will give the TASC photon spectra for BATSE bursts apparent in the TASC Burst mode. The BULTCRVfiles will give the TASC and anticoincidence-dome light curves for BATSE bursts apparent in the TASC Burst mode. The SOLRCATfile will contain a catalog of solar flares apparent in the TASC Solar mode. The SOLARPSfiles will give the TASC photon spectra for solar flares apparent in the TASC solar mode. The SOLTCRVfiles will give the TASC and anticoincidence-dome light curves for solar flares apparent in the TASC solar mode. For gamma-ray bursts, or solar flares where gamma rays are detected with the EGRET spark chamber, SELECTFiles will be available containing the spark-chamber events. This will be noted in BURSCATfile or SOLRCATfile.

The DIFFMAPfiles will be binned FITS formats which contain the results of the EGRET team diffuse emission studies. The galactic plane result will be a separate file. The format of the high galactic latitude maps is currently not certain (i.e. either an Aitoff projection, or regional maps). It is expected that DIFFMAPfiles will be made available in different resolutions. The highest resolution possible will be the resolution of the radio surveys used.

The EGRETPBfile will be an annotated list of publications by the EGRET team and GIs resulting from EGRET data.

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